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11. BODY WEIGHT STUDIES

11.1 INTRODUCTION

The average daily dose is typically normalized to the average body weight of the exposed population. If exposure occurs only during childhood years, the average child body weight during the exposure period should be used to estimate risk (U.S. EPA, 1989).

The purpose of this section is to describe key published studies on body weight for children in the general U.S. population, as described in the *Exposure Factors Handbook* (U.S. EPA, 1997). Recommended values are based on the results of these studies.

11.2 BODY WEIGHT STUDIES

Hamill et al. (1979) - Physical Growth: National Center for Health Statistics Percentiles- A National Center for Health Statistics (NCHS) Task Force that included academic investigators and representatives from CDC Nutrition Surveillance Program selected, collated, integrated, and defined appropriate data sets to generate growth curves for the age interval: birth to 36 months developed (Hamill et al., 1979). The percentile curves were for assessing the physical growth of children in the U.S. They are based on accurate measurements made on large nationally representative samples of children (Hamill et al., 1979). Smoothed percentile curves were derived for body weight by age (Hamill et al., 1979). Curves were developed for boys and for girls. The data used to construct the curves were provided by the Fels Research Institute, Yellow Springs, Ohio. These data were from an ongoing longitudinal study where anthromopetric data from direct measurements are collected regularly from participants (~1,000) in various areas of the U.S. The NCHS used advanced statistical and computer technology to generate the growth curves. Table 11-1 presents the percentiles of weight by sex and age. Figures 11-1 and 11-2 present weight by age percentiles for boys and for girls aged birth to 36 months, respectively. Limitations of this study are that mean body weight values were not reported and the data are more that 15 years old. However, this study does provide body weight data for infants less than 6 months old.

NCHS (1987) - Anthropometric Reference Data and Prevalence of Overweight, United States, 1976-80 - Statistics on anthropometric measurements, including body weight, for the U.S. population were collected by NCHS through the second National Health and Nutrition

Examination Survey (NHANES II). NHANES II was conducted on a nationwide probability sample of approximately 28,000 persons, aged 6 months to 74 years, from the civilian, non-institutionalized population of the United States. Of the 28,000 persons, 20,322 were interviewed and examined, resulting in a response rate of 73.1 percent. The survey began in February 1976 and was completed in February 1980. The sample was selected so that certain subgroups thought to be at high risk of malnutrition (persons with low incomes, preschool children, and the elderly) were oversampled. The estimates were weighted to reflect national population estimates. The weighting was accomplished by inflating examination results for each subject by the reciprocal of selection probabilities adjusted to account for those who were not examined, and post stratifying by race, age, and sex (NCHS, 1987).

The NHANES II collected standard body measurements of sample subjects, including height and weight, that were made at various times of the day and in different seasons of the year. This technique was used because one's weight may vary between winter and summer and may fluctuate with recency of food and water intake and other daily activities (NCHS, 1987). Mean body weights and standard deviations for children, ages 6 months to 19 years, are presented in Table 11-2 for boys, girls, and boys and girls combined. Percentile data for children, by age, are presented in Table 11-3 for males, and in Table 11-4 for females. From Table 11-2, the mean body weights for girls and boys are approximately the same from ages 6 months to 14 years. Starting at years 15-19, the difference in mean body weight ranges from 6 to 11 kg.

Burmaster et al. (1997)- Lognormal Distributions for Body Weight as a Function of Age for Males and Females in the United States, 1976-1980 - Burmaster et al. (1997) performed data analysis to fit normal and lognormal distributions to the body weights of females and males at age 9 months to 70 years (Burmaster et al., 1997). The 1997 *Exposure Factors Handbook* used a pre-published version of this paper (U.S. EPA, 1997). The numbers reported in Tables 11-5 and 11-6 vary slightly from those reported in the *Exposure Factors Handbook* (U.S. EPA, 1997).

Data used in this analysis were from the second survey of the National Center for Health Statistics, NHANES II, which included 27,801 persons 6 months to 74 years of age in the U.S. (Burmaster et al., 1997). The NHANES II data had been statistically adjusted for non-response and probability of selection, and stratified by age, sex, and race to reflect the entire U.S. population prior to reporting (Burmaster et al., 1997). Burmaster et al. (1997) conducted exploratory and quantitative data analyses, and fit normal and lognormal distributions to

percentiles of body weights of children, teens, and adults as a function of age. Cumulative distribution functions (CDFs) were plotted for female and male body weights on both linear and logarithmic scales.

Two models were used to assess the probability density functions (PDFs) of children's body weight. Linear and quadratic regression lines were fitted to the data. A number of goodness-of-fit measures were conducted on data generated by the two models. Burmaster et al. (1997) found that lognormal distributions give strong fits to the data for each sex across all age groups. Statistics for the lognormal probability plots for children, ages 9 months to 20 years, are presented in Tables 11-5 and 11-6. These data can be used for further analyses of body weight distribution (i.e., application of Monte Carlo analysis).

U.S. EPA, 2000 - Body Weight Estimates Based on NHANES III Data - The EPA Office of Water has estimated body weights for children, in kilograms, by age and gender using data collected during National Health and Nutrition Examination Survey III (NHANES III), 1988-1994. NHANES III collected body weight data for approximately 15,000 children between the ages of 2 months and 17 years. Table 11-7 Presents the body weight estimates in kilograms by age and gender. Table 11-8 shows the body weight estimates for the infants under the age of 3 months and/or younger, while Figures 11-3 and 11-4 compare the body weights (mean and median) between male and female among various age groups, respectively.

The limitations of these data are (1) the data were not available for infants under 2 months old, and (2) the data are roughly 6-12 years old. With the upward trends in body weight from NHANES II (1976-1980) to NHANES III which may still be valid, the data in Tables 11-7 and 11-8 may underestimate current body weights. Adjustment factors may be needed to update the estimates from 1988-1994 data to 2000. However, the data are national in scope and represent the general children’s population.

11.3 RECOMMENDATIONS

The recommended values for body weight are summarized in Table 11-9. Table 11-10 presents the confidence ratings for body weight recommendations.

For infants (birth to 6 months), appropriate values for body weight may be selected from Table 11-1. These data (percentile only) are presented for male and female infants.

For children, appropriate mean values for weights may be selected from Table 11-2. If percentile values are needed, these data are presented in Table 11-3 for male children and in Table 11-4 for female children.

11.4 REFERENCES FOR CHAPTER 11

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Table 11-1. Smoothed Percentiles of Weight (In Kg) by Sex And Age:
Statistics From NCHS And Data From Fels Research Institute, Birth to 36 Months

	Smoothed[a] Percentile						
	5th	10th	25th	50th	75th	90th	95th
Sex and Age	Weight in Kilograms						
Male							
Birth	2.54	2.78	3.00	3.27	3.64	3.82	4.15
1 Month	3.16	3.43	3.82	4.29	4.75	5.14	5.38
3 Months	4.43	4.78	5.32	5.98	6.56	7.14	7.37
6 Months	6.20	6.61	7.20	7.85	8.49	9.10	9.46
9 Months	7.52	7.95	8.56	9.18	9.88	10.49	10.93
12 Months	8.43	8.84	9.49	10.15	10.91	11.54	11.99
18 Months	9.59	9.92	10.67	11.47	12.31	13.05	13.44
24 Months	10.54	10.85	11.65	12.59	13.44	14.29	14.70
30 Months	11.44	11.80	12.63	13.67	14.51	15.47	15.97
36 Months	12.26	12.69	13.58	14.69	15.59	16.66	17.28
Female							
Birth	2.36	2.58	2.93	3.23	3.52	3.64	3.81
1 Month	2.97	3.22	3.59	3.98	4.36	4.65	4.92
3 Months	4.18	4.47	4.88	5.40	5.90	6.39	6.74
6 Months	5.79	6.12	6.60	7.21	7.83	8.38	8.73
9 Months	7.00	7.34	7.89	8.56	9.24	9.83	10.17
12 Months	7.84	8.19	8.81	9.53	10.23	10.87	11.24
18 Months	8.92	9.30	10.04	10.82	11.55	12.30	12.76
24 Months	9.87	10.26	11.10	11.90	12.74	13.57	14.08
30 Months	10.78	11.21	12.11	12.93	13.93	14.81	15.35
36 Months	11.60	12.07	12.99	13.93	15.03	15.97	16.54

[a]Smoothed by cubic-spline approximation.

Source: Hamill et al. (1979).

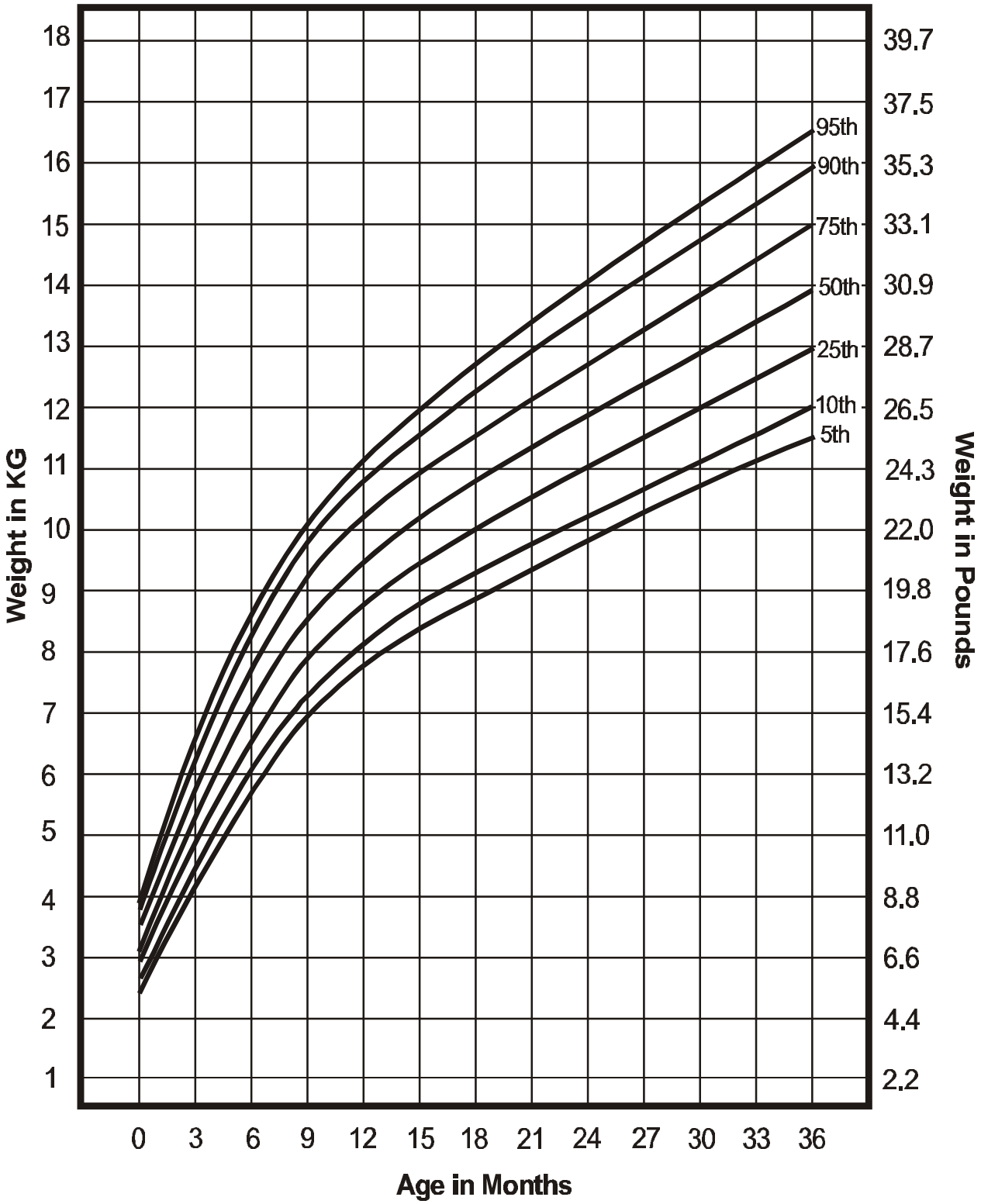


Figure 11-1. Weight by Age percentiles for Girls Aged Birth-36 Months

Source: Hamill et al. (1979).

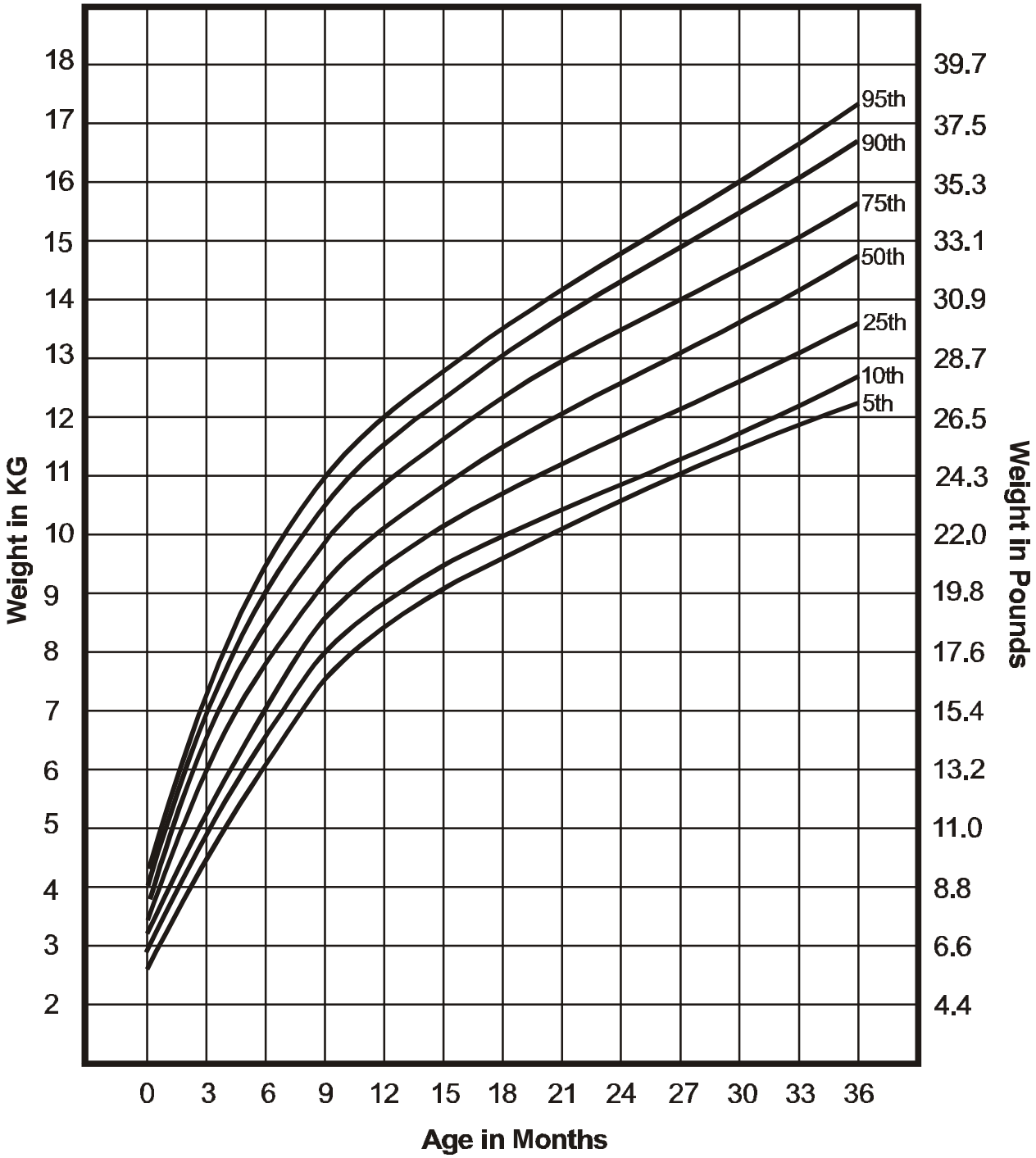
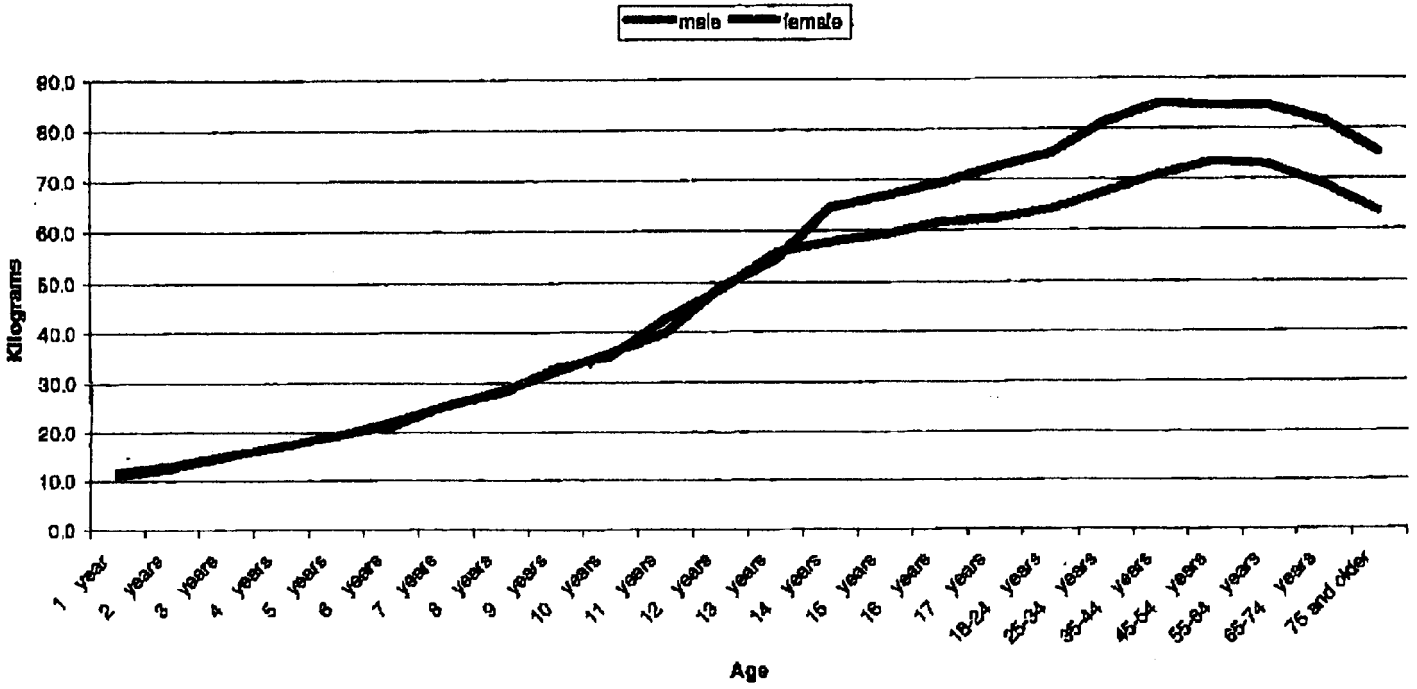


Figure 11-2: Weight by Age Percentiles for Boys Aged Birth-36 Months

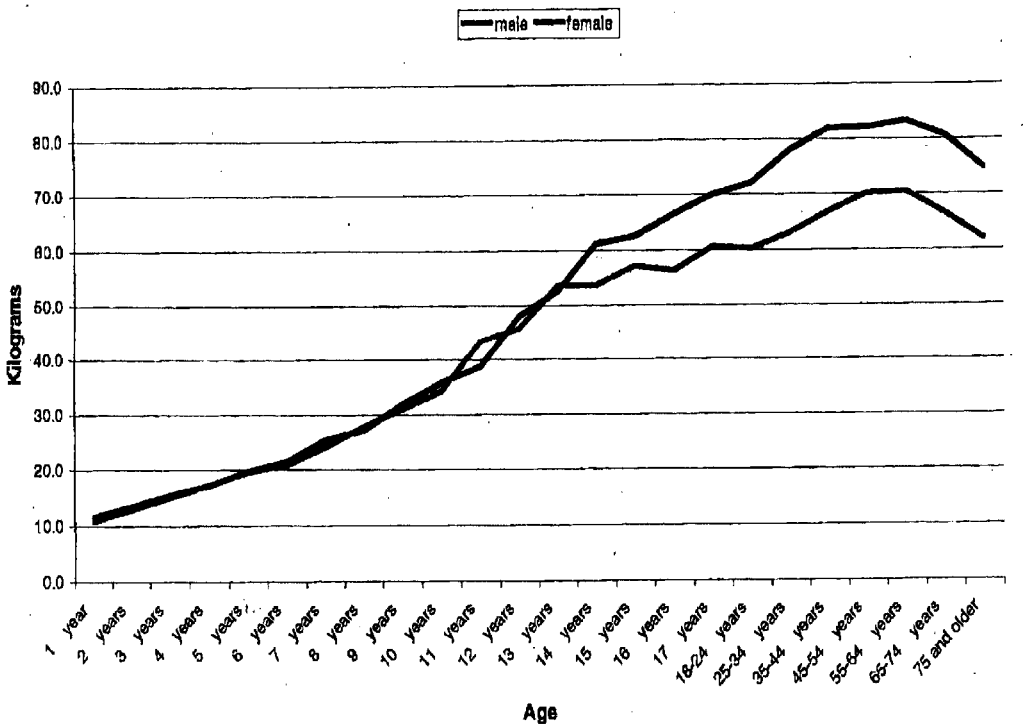
Source: Hamill et al. (1979).

Figure 11-3. Mean Body Weights Estimates, U.S. Population, 1988-94



Source: U.S. EPA (2000).

Figure 11-4. Median Body Weights Estimates, U.S. Population, 1988-94



Source: U.S. EPA (2000).

Table 11-2. Body Weights of Children[a] (Kilograms)

	Boys		Girls		Boys and Girls
Age	Mean (kg)	Std. Dev.	Mean (kg)	Std. Dev.	Mean (kg)
6-11 months	9.4	1.3	8.8	1.2	9.1
1 year	11.8	1.9	10.8	1.4	11.3
2 years	13.6	1.7	13.0	1.5	13.3
3 years	15.7	2.0	14.9	2.1	15.3
4 years	17.8	2.5	17.0	2.4	17.4
5 years	19.8	3.0	19.6	3.3	19.7
6 years	23.0	4.0	22.1	4.0	22.6
7 years	25.1	3.9	24.7	5.0	24.9
8 years	28.2	6.2	27.9	5.7	28.1
9 years	31.1	6.3	31.9	8.4	31.5
10 years	36.4	7.7	36.1	8.0	36.3
11 years	40.3	10.1	41.8	10.9	41.1
12 years	44.2	10.1	46.4	10.1	45.3
13 years	49.9	12.3	50.9	11.8	50.4
14 years	57.1	11.0	54.8	11.1	56.0
15 years	61.0	11.0	55.1	9.8	58.1
16 years	67.1	12.4	58.l	10.1	62.6
17 years	66.7	11.5	59.6	11.4	63.2
18 years	71.1	12.7	59.0	11.1	65.1
19 years	71.7	11.6	60.2	11.0	66.0

Note: 1 kg = 2.2046 pounds.

[a]Includes clothing weight, estimated as ranging from 0.09 to 0.28 kilogram.

Source: Adapted from National Center for Health Statistics (NCHS) (1987).

Table 11-3. Weight in Kilograms For Males 6 Months-19 Years of Age–number Examine, Mean, Standard Deviation, and Selected Percentiles, by Sex and Age: United States, 1976-1980[a]

Age	Number of Persons Examined	Mean (kg)	Standard Deviation	Percentile								
				5th	10th	15th	25th	50th	75th	85th	90th	95th
6-11 months	179	9.4	1.3	7.5	7.6	8.2	8.6	9.4	10.1	10.7	10.9	11.4
1 years	370	11.8	1.9	9.6	10.0	10.3	10.8	11.7	12.6	13.1	13.6	14.4
2 years	375	13.6	1.7	11.1	11.6	11.8	12.6	13.5	14.5	15.2	15.8	16.5
3 years	418	15.7	2.0	12.9	13.5	13.9	14.4	15.4	16.8	17.4	17.9	19.1
4 years	404	17.8	2.5	14.1	15.0	15.3	16.0	17.6	19.0	19.9	20.9	22.2
5 years	397	19.8	3.0	16.0	16.8	17.1	17.7	19.4	21.3	22.9	23.7	25.4
6 years	133	23.0	4.0	18.6	19.2	19.8	20.3	22.0	24.1	26.4	28.3	30.1
7 years	148	25.1	3.9	19.7	20.8	21.2	22.2	24.8	26.9	28.2	29.6	33.9
8 years	147	28.2	6.2	20.4	22.7	23.6	24.6	27.5	29.9	33.0	35.5	39.1
9 years	145	31.1	6.3	24.0	25.6	26.0	27.1	30.2	33.0	35.4	38.6	43.1
10 years	157	36.4	7.7	27.2	28.2	29.6	31.4	34.8	39.2	43.5	46.3	53.4
11 years	155	40.3	10.1	26.8	28.8	31.8	33.5	37.3	46.4	52.0	57.0	61.0
12 years	145	44.2	10.1	30.7	32.5	35.4	37.8	42.5	48.8	52.6	58.9	67.5
13 years	173	49.9	12.3	35.4	37.0	38.3	40.1	48.4	56.3	59.8	64.2	69.9
14 years	186	57.1	11.0	41.0	44.5	46.4	49.8	56.4	63.3	66.1	68.9	77.0
15 years	184	61.0	11.0	46.2	49.1	50.6	54.2	60.1	64.9	68.7	72.8	81.3
16 years	178	67.1	12.4	51.4	54.3	56.1	57.6	64.4	73.6	78.1	82.2	91.2
17 years	173	66.7	11.5	50.7	53.4	54.8	58.8	65.8	72.0	76.8	82.3	88.9
18 years	164	71.1	12.7	54.1	56.6	60.3	61.9	70.4	76.6	80.0	83.5	95.3
19 years	148	71.7	11.6	55.9	57.9	60.5	63.8	69.5	77.9	84.3	86.8	82.1

Note: 1 kg = 2.2046 pounds.

[a]Includes clothing weight, estimated as ranging from 0.09 to 0.28 kilogram.

Source: National Center for Health Statistics (1987).

Table 11-4. Weight in Kilograms For Females 6 Months-19 Years of Age - Number Examine, Mean, Standard Deviation, And Selected Percentiles, By Sex And Age: United States, 1976-1980[a]

Age	Number of Persons Examined	Mean (kg)	Standard Deviation	Percentile								
				5th	10th	15th	25th	50th	75th	85th	90th	95th
6-11 months	177	8.8	1.2	6.6	7.3	7.5	7.9	8.9	9.4	10.1	10.4	10.9
1 years	336	10.8	1.4	8.8	9.1	9.4	9.9	10.7	11.7	12.4	12.7	13.4
2 years	336	13.0	1.5	10.8	11.2	11.6	12.0	12.7	13.8	14.5	14.9	15.9
3 years	366	14.9	2.1	11.7	12.3	12.9	13.4	14.7	16.1	17.0	17.4	18.4
4 years	396	17.0	2.4	13.7	14.3	14.5	15.2	16.7	18.4	19.3	20.2	21.1
5 years	364	19.6	3.3	15.3	16.1	16.7	17.2	19.0	21.2	22.8	24.7	26.6
6 years	135	22.1	4.0	17.0	17.8	18.6	19.3	21.3	23.8	26.6	28.9	29.6
7 years	157	24.7	5.0	19.2	19.5	19.8	21.4	23.8	27.1	28.7	30.3	34.0
8 years	123	27.9	5.7	21.4	22.3	23.3	24.4	27.5	30.2	31.3	33.2	36.5
9 years	149	31.9	8.4	22.9	25.0	25.8	27.0	29.7	33.6	39.3	43.3	48.4
10 years	136	36.1	8.0	25.7	27.5	29.0	31.0	34.5	39.5	44.2	45.8	49.6
11 years	140	41.8	10.9	29.8	30.3	31.3	33.9	40.3	45.8	51.0	56.6	60.0
12 years	147	46.4	10.1	32.3	35.0	36.7	39.1	45.4	52.6	58.0	60.5	64.3
13 years	162	50.9	11.8	35.4	39.0	40.3	44.1	49.0	55.2	60.9	66.4	76.3
14 years	178	54.8	11.1	40.3	42.8	43.7	47.4	53.1	60.3	65.7	67.6	75.2
15 years	145	55.1	9.8	44.0	45.1	46.5	48.2	53.3	59.6	62.2	65.5	76.6
16 years	170	58.1	10.1	44.1	47.3	48.9	51.3	55.6	62.5	68.9	73.3	76.8
17 years	134	59.6	11.4	44.5	48.9	50.5	52.2	58.4	63.4	68.4	71.6	81.8
18 years	170	59.0	11.1	45.3	49.5	50.8	52.8	56.4	63.0	66.0	70.1	78.0
19 years	158	60.2	11.0	48.5	49.7	51.7	53.9	57.1	64.4	70.7	74.8	78.1

Note: 1 kg = 2.2046 pounds.

[a] Includes clothing weight, estimated as ranging from 0.09 to 0.28 kilogram.

Source: National Center for Health Statistics (1987).

Table 11-5. Best-fit Parameters for Lognormal Distributions

	Lognormal Probability Plots Linear Curve	
Age Midpoint (yr)	μ_2[a]	σ_2[a]
0.75	2.16	0.145
1.5	2.38	0.129
2.5	2.56	0.112
3.5	2.69	0.136
4.5	2.83	0.134
5.5	2.98	0.164
6.5	3.10	0.174
7.5	3.19	0.174
8.5	3.31	0.156
9.5	3.46	0.214
10.5	3.57	0.199
11.5	3.71	0.226
12.5	3.82	0.213
13.5	3.92	0.215
14.5	3.99	0.187
15.5	4.00	0.156
16.5	4.05	0.167
17.5	4.08	0.165
18.5	4.07	0.147
19.5	4.10	0.149

[a]μ_2, σ_2 - correspond to the mean and standard deviation, respectively, of the lognormal distribution of body weight (kg).

Source: Burmaster et al. (1997).

Table 11-6. Statistics for Probability Plot Regression Analyses
Male's Body Weights 6 Months to 20 Years of Age

Age Midpoint (yrs)	Lognormal Probability Plots Linear Curve	
	μ_2[a]	σ_2[a]
0.75	2.23	0.132
1.5	2.46	0.119
2.5	2.60	0.120
3.5	2.75	0.114
4.5	2.87	0.133
5.5	2.98	0.138
6.5	3.13	0.145
7.5	3.21	0.151
8.5	3.33	0.181
9.5	3.43	0.165
10.5	3.59	0.195
11.5	3.69	0.252
12.5	3.78	0.224
13.5	3.88	0.215
14.5	4.02	0.181
15.5	4.09	0.159
16.5	4.20	0.168
17.5	4.19	0.167
18.5	4.25	0.159
19.5	4.26	0.154

[a]μ_2, σ_2 - correspond to the mean and standard deviation, respectively, of the lognormal distribution of body weight (kg).

Source: Burmaster et al. (1997).

Table 11-7. Body Weight Estimates (in kilograms) by Age and Gender, U.S. Population 1988-94

Age	Sample Size	Population	Male and Female		Male		Female	
			Median	Mean	Median	Mean	Median	Mean
2-6 months	1,020	1,732,702	7.4	7.4	7.6	7.7	7.0	7.0
7-12 months	1,072	1,925,573	9.4	9.4	9.7	9.7	9.1	9.1
1 year	1,258	3,935,114	11.3	11.4	11.7	11.7	10.9	11.0
2 years	1,513	4,459,167	13.2	12.9	13.5	13.1	13.0	12.5
3 years	1,309	4,317,234	15.3	15.1	15.5	15.2	15.1	14.9
4 years	1,284	4,008,079	17.2	17.1	17.2	17.0	17.3	17.2
5 years	1,234	4,298,097	19.6	19.4	19.7	19.3	19.6	19.4
6 years	750	3,942,457	21.3	21.7	21.5	22.1	20.9	21.3
7 years	736	4,064,397	25.0	25.5	25.4	25.5	24.1	25.6
8 years	711	3,863,515	27.4	28.1	27.2	28.4	27.9	27.9
9 years	770	4,385,199	31.8	32.7	32.0	32.3	31.1	33.0
10 years	751	3,991,345	35.2	35.6	35.9	36.0	34.3	35.2
11 years	754	4,270,211	40.6	41.5	38.8	40.0	43.4	42.8
12 years	431	3,497,661	47.2	46.9	48.1	49.1	45.7	48.6
13 years	428	3,567,181	53.0	55.1	52.6	54.5	53.7	55.9
14 years	415	4,054,117	56.9	61.1	61.3	64.5	53.7	57.9
15 years	378	3,269,777	59.6	62.8	62.6	66.9	57.1	59.2
16 years	427	3,652,041	63.2	65.8	66.6	69.4	56.3	61.6
17 years	410	3,719,690	65.1	67.5	70.0	72.4	60.7	62.2
1 and older	31,311	251,097,002	66.5	64.5	73.9	89.0	80.8	80.3
1-3 years	4,080	12,711,515	13.2	13.1	13.4	13.4	13.0	12.9
1-14 years	12,344	56,653,796	24.9	29.9	25.1	30.0	24.7	29.7
15-44 years	10,393	118,430,653	70.8	73.5	77.5	80.2	63.2	67.3

Source: U.S. EPA, 2000.

Table 11-8. Body Weight Estimates (in kilograms) by Age, U.S. Population 1988-94

			Male and Female		
Age	Sample Size	Population	Median	Mean	95% CI
Newborn	NA	NA	NA	NA	NA
1 Month	NA	NA	NA	NA	NA
2 Months	243	408,837	6.3	6.3	6.1-6.4
3 Months	190	332,823	7.0	6.9	6.7-7.1
3 Months and Younger	433	741,660	6.6	6.6	6.4-6.7

NA = Not available.
CI = Confidence Intervals.

Source: U.S. EPA (2000).

Table 11-9. Summary of Recommended Values for Body Weight

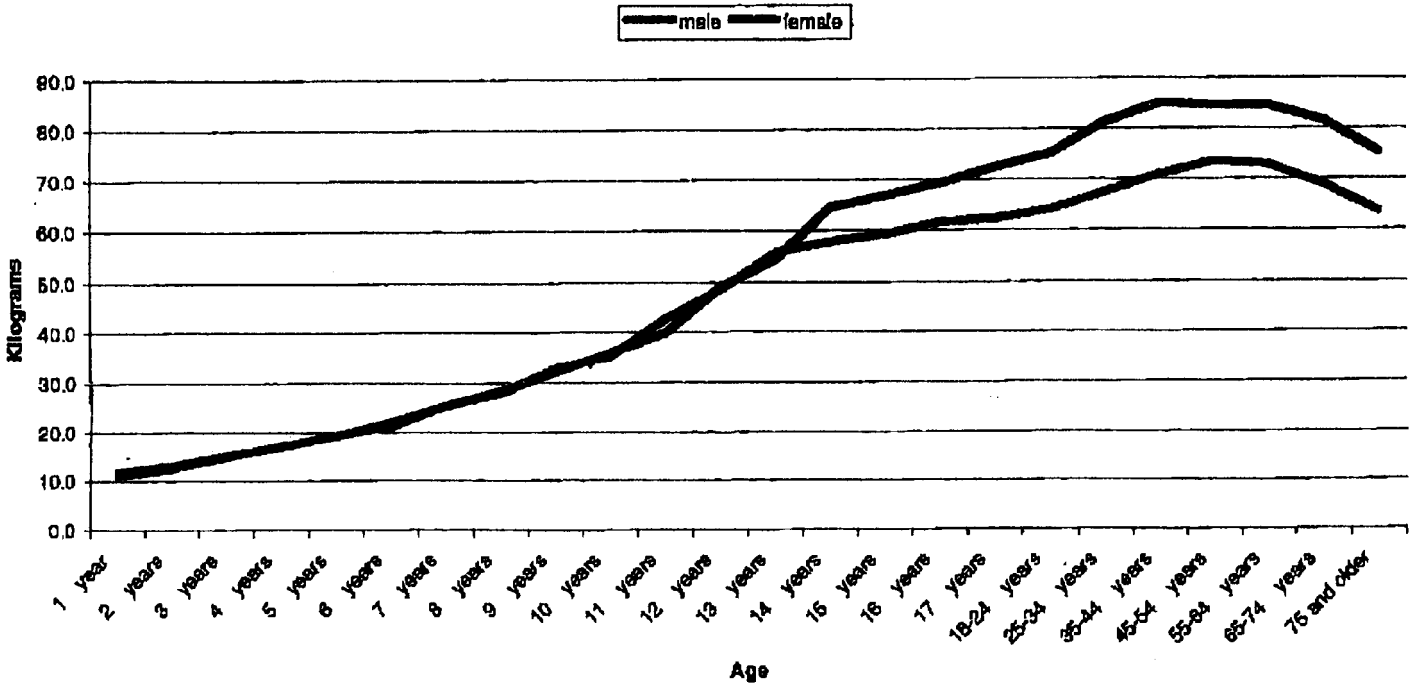
Population	Mean	Upper Percentile	Multiple Percentiles
Children	See Table 11-2	See Tables 11-3 and 11-4	See Tables 11-3 and 11-4
Infants	Not Available	See Table 11-1	See Table 11-1

1
2

Table 11-10. Confidence in Body Weight Recommendations

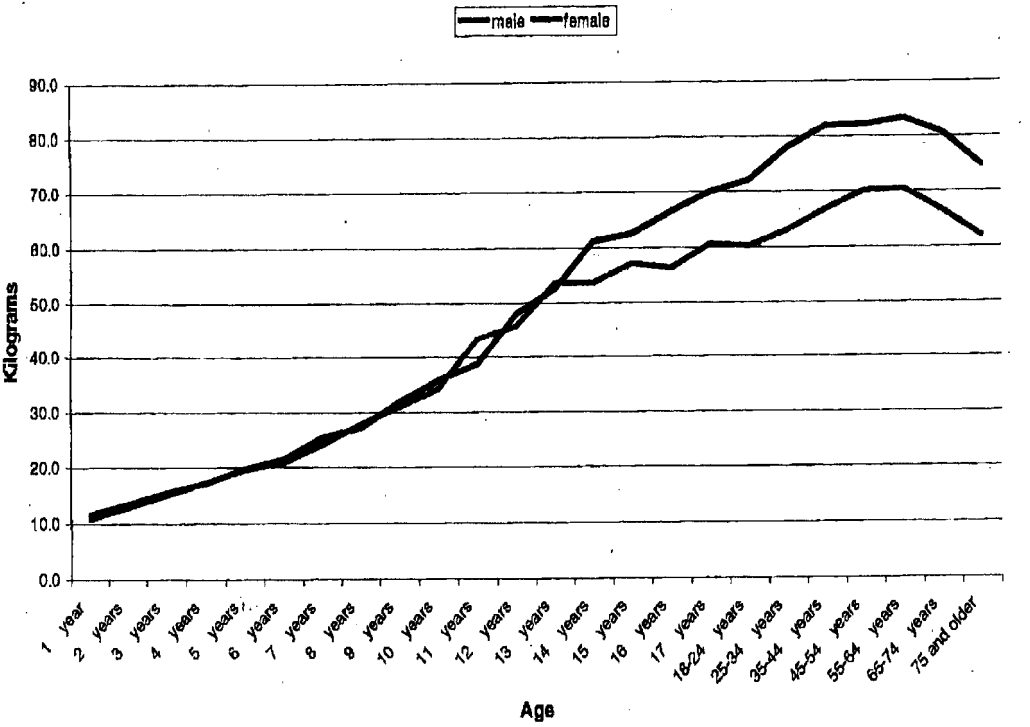
Considerations	Rationale	Rating
Study Elements		
• Level of peer review	NHANES II was the major source of data for NCHS (1987). This is a published study which received a high level of peer review. The Hamill et al. (1979) is a peer reviewed journal publication.	High
• Accessibility	Both studies are available to the public.	High
• Reproducibility	Results can be reproduced by analyzing NHANES II data and the Fels Research Institute data.	High
• Focus on factor of interest	The studies focused on body weight, the exposure factor of interest.	High
• Data pertinent to US	The data represent the U.S. population.	High
• Primary data	The primary data were generated from NHANES II data and Fels studies, thus these data are secondary.	Medium
• Currency	The data were collected between 1976-1980.	Low
• Adequacy of data collection period	The NHANES II study included data collected over a period of 4 years. Body weight measurements were taken at various times of the day and at different seasons of the year.	High
• Validity of approach	Direct body weights were measured for both studies. For NHANES II, subgroups at risk for malnutrition were over-sampled. Weighting was accomplished by inflating examination results for those not examined and were stratified by race, age, and sex. The Fels data are from an ongoing longitudinal study where the data are collected regularly.	High
• Study size	The sample size consisted of 28,000 persons for NHANES II. Author noted in Hamill et al. (1979) that the data set was large.	High
• Representativeness of the population	Data collected focused on the U.S. population for both studies.	High
• Characterization of variability	Both studies characterized variability regarding age and sex. Additionally NHANES II characterized race (for Blacks, Whites and total populations) and sampled persons with low income.	High
• Lack of bias in study design (high rating is desirable)	There are no apparent biases in the study designs for NHANES II. The study design for collecting the Fels data was not provided.	Medium-High
• Measurement error	For NHANES II, measurement error should be low since body weights were performed in a mobile examination center using standardized procedures and equipment. Also, measurements were taken at various times of the day to account for weight fluctuations as a result of recent food or water intake. The authors of Hamill et al. (1979) report that study data are based on accurate direct measurements from an ongoing longitudinal study.	High
Other Elements		
• Number of studies	There are two studies.	Low
• Agreement between researchers	There is consistency among the two studies.	High
Overall Rating		**High**

Figure 11-3. Mean Body Weights Estimates, U.S. Population, 1988-94



Source: U.S. EPA (2000).

Figure 11-4. Median Body Weights Estimates, U.S. Population, 1988-94



Source: U.S. EPA (2000).